Rearing of Chinook Salmon (*Oncorhynchus tshawytscha*) in Cold Water: Kalum Pilot Hatchery Experience

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July 1987

Canadian Manuscript Report of
Fisheries and Aquatic Sciences
No. 1943

Fisheries and Oceans Pêches et Océans

Canada

88-01597/

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Rearing of chinook salmon (*Oncorhynchus tshawytscha*) in cold water: Kalum Pilot Hatchery experiences 1980-1983

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No. 1943

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Cat. No. FS 97-4/1943 ISSN 0706 6473

Correct citation for this publication:

MacKinlay, D.D. and R.F. Fielden. 1987. Rearing of chinook salmon (Oncorhynchus tshawytscha) in cold water: Kalum Pilot Hatchery experiences 1980-1983. Can. MS Rep. Fish. Aquat. Sci. 1943. 47p.

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ABSTRACT

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Chinook salmon (Oncorhynchus tshawytscha) were incubated and reared in a pilot-scale facility to assess the feasibility of using the Dry Creek spring water source as the water supply for a production-scale facility and to begin assessment of release strategies for a Skeena chinook stock. The two groundwater springs 35 km north of Terrace, B.C. produce a total of 50,000 LPM of water which ranges from over 6.5°C in winter to less than 4.5°C in summer. Gravel box incubation in ambient water resulted in unacceptably prolonged emergence in the decreasing temperature regimes. Vertical tray incubation allowed better control of ponding timing. Heating the water allowed for earlier ponding, better initiation of feeding and a longer rearing period, resulting in 4 g+ release size, compared to less than 2 g for ambient water, although once feeding was initiated in warm water, the growth rates were similar for heated and unheated test groups.

RÉSUMÉ

MacKinlay, D.D. and R.F. Fielden. 1987. Rearing of chinook salmon (Oncorhynchus tshawytscha) in cold water: Kalum Pilot Hatchery experiences 1980-1983. Can. MS Rep. Fish. Aquat. Sci. 1943. 47p

Une installation pilote a servi pour l'incubation d'oeufs et l'alevinage de saumon quinnat (Oncorhynchus tshawytscha) afin de déterminer si la source du ruisseau Dry peut alimenter une installation de taille normale et d'évaluer des stratégies de lâcher pour la mise en valeur du stock de la Skeena. Les deux sources d'eau souterraine situées à 35 km au nord de Terrace (C.-B.) produisent un total de 50 000 LPM d'eau dont la température va de plus de 6,5°C en hiver à moins de 4,5°C en été. L'incubation en eau de température ambiante dans des bacs à substrat de gravier a entraîné un report inacceptable de l'émergence

quand la température de l'eau baissait. Par contre, l'incubation sur des claies verticales a permis un meilleur contrôle du moment du déversement en étangs. Le réchauffement de l'eau a aussi permis un déversement plus rapide des alevins en étangs, l'initiation précoce de la consommation d'aliments et une plus longue période d'alevinage; ainsi, les poissons pesaient 4 g^+ contre moins de 2 g en eau à température ambiante, au moment du lâcher. Par contre, les taux de croissance étaient semblables chez les groupes témoins gardés en milieu chauffé et non chauffé dès le début de l'alimentation en eau réchauffée.

INTRODUCTION

STUDY LOCATION

The Kalum Pilot Hatchery site was located 35 km north of Terrace, B.C., near the north end of Kitsumkalum Lake (Figure 1). Helicopter reconnaissance of the area in 1979, as part of a general search for potential facility sites by the Salmonid Enhancement Program (Shepherd, 1984), identified Dry Creek as warm enough to stay ice free during the winter. Such water sources were of interest because of their potential to accelerate the development of salmon eggs and fry and produce larger-than-normal fish for release, with possible increased survival.

Dry Creek emanates from two groundwater springs which are 145 m apart and produce a total discharge of about 50,000 LPM. The upper spring water comes out of the hillside and flows 80 m to meet the lower spring water 30 m from its source. Just below the confluence of the two flows the creek entered a 1.0 ha beaver pond, from which it flowed about 500 m through a road culvert and into a slough near the mouth of Clear Creek on Kitsumkalum Lake.

The springs and beaver pond are located on privately-owned land. The site was reached by gravel road from Terrace which runs along the east side of Kitsumkalum Lake. The road crosses Dry Creek just south of the entrance to the small side road which leads to the site.

Nearby Clear Creek was thought potentially suitable as a surface water supply if a facility were constructed at the Dry Creek site.

PROJECT OBJECTIVES

The Kalum Pilot Hatchery was operated for three years. The first two years assessed the suitability of the site for future development as a hatchery for chinook salmon (Oncorhynchus tshawytscha). The last year produced different sizes of juvenile chinook to assist in defining suitable release strategies for northern (particularly Skeena) stocks.

The Kalum Pilot used chinook salmon as the test species because of the shorter time required to rear them to smolt size and because they were the primary target for enhancement in the area. Chinook are normally released the year they emerge rather than being reared over the following winter as are coho. The two

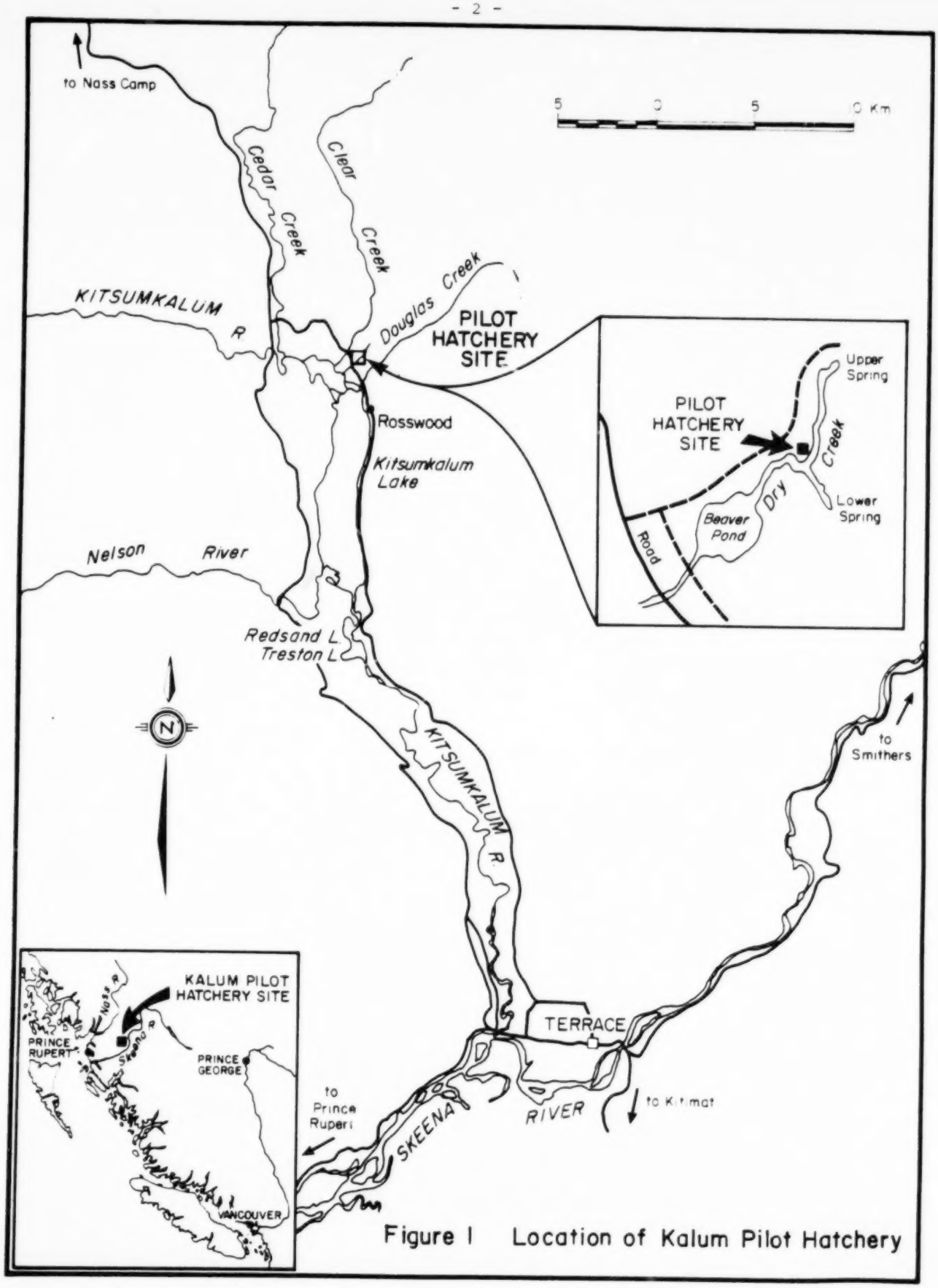


Figure 1 Location of Kalum Pilot Hatchery

main local stocks are the early-spawning Cedar stock and the later-spawning lower Kitsumkalum stock.

Pilot I

Preliminary water temperature monitoring indicated that Dry Creek produced water in excess of 6.5°C during mid-winter, but the temperature dropped to below 4.5°C by summer. It was assumed that the higher-than-ambient fall and winter temperatures would lead to accelerated development of eggs and early swim-up of fry, requiring provision for manpower and facilities for rearing in mid-winter. The purpose of the first pilot was to produce 2 g fry by release in late May under a temperature regime that was declining below 5.5°C. Different types of fish food (Oregon Moist Pellet [OMP] versus Biodiet) also were to be tested to see on which food the fish reared better in cold water.

A target of 50,000 eggs from each of the lower Kitsumkalum and the Cedar stocks were to be taken the first year. Delays in getting the facility operational altered the target to 100,000 eggs from the lower Kitsumkalum only.

Pilot II

The second year looked at the option of heating water during critical stages of culture, particularly during early rearing to ensure that a strong initial feeding response was induced in the fish. Growth rates between heated and unheated lots of fish were to be compared to assess the benefit of heating water. Various combinations of heating and timing were to be used to determine when the best time to heat would be.

Pilot III

Once the basic ability to produce smolt-sized fish was shown in Pilot II, techniques were refined to allow experimentation with size of released juveniles. Enough fish were to be reared to provide a valid statistical analysis of the adult returns from 2 g and 5 g fish released from the facility. Targets were set at 50,000 tags for each size.

The heated water was to be partially recirculated to reduce the heating costs and increase the temperature differential between heated and un-heated rearing water.

METHODS

FACILITIES

The Department of Fisheries and Oceans obtained permission to use some of the spring water and occupy land adjacent to the beaver pond through a lease negotiated with the landowner. The pilot facility (Figure 2) was located at an elevation 9 m below the upper spring and 2 m below the lower spring. A screened, in-stream intake (Figure 3) was constructed 40 m downstream of the upper spring. A back-up intake, consisting of a perforated 500 mm diameter PVC standpipe buried in the streambed gravel in a vertical position, was installed in the lower spring. A 100 mm diameter PVC plastic supply pipe line ran in-stream (to prevent freezing) from each intake to join into a single pipe which fed the incubation and rearing facilities. The landowner had constructed a rock gabion dam at the upper spring to supply water to a small hydroelectric plant. Although there was less water available for the hatchery while the turbine was in operation, the reduced flow was considered advantageous for aerating the water more effectively before it entered the intake.

Pilot I

For Pilot I in 1980/81 (Figure 4), the incubation facilities consisted of two 75,000-egg upwelling, gravel incubation boxes (Figure 5). The eggs were planted in two wood-framed trays placed on top of the gravel. The bottom of the trays were made of Vexar screen which supported the eggs yet allowed the alevins to descend into the gravel upon hatching. This type of incubation unit has been described in more detail by Federenko and Bailey (1980).

The fry were reared in two Capilano style troughs (Figure 6). These troughs are 6.4 m long and contain about 2.2 m^3 of rearing space. The standard SEP loading criteria is 40,000 chinook fry (up to 1.5 g size) per trough at a maximum flow of 240 LPM per line of two troughs. The first two troughs installed at Kalum were not in line and were buried in the ground to allow them to receive the flow from the incubation boxes. An 8 m long travel trailer was used by hatchery personnel as office, lab and sleeping quarters.

Pilot II

For Pilot II in 1981/82 (Figure 7) incubation capacity was expanded to 200,000 eggs by the addition of an eight-tray incubator stack (Figure 8). For rearing, four more Capilano troughs were installed in two lines beside the original

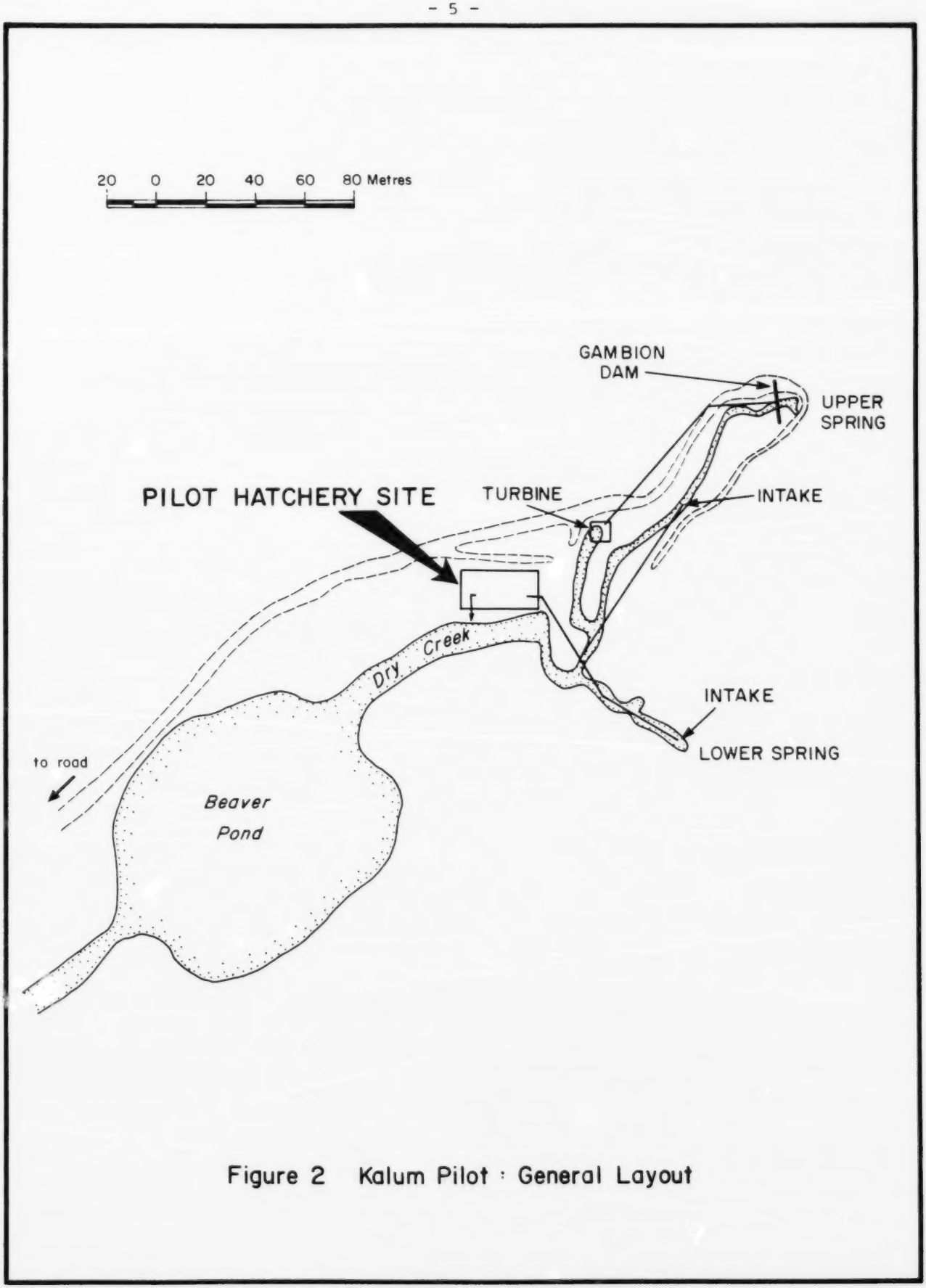
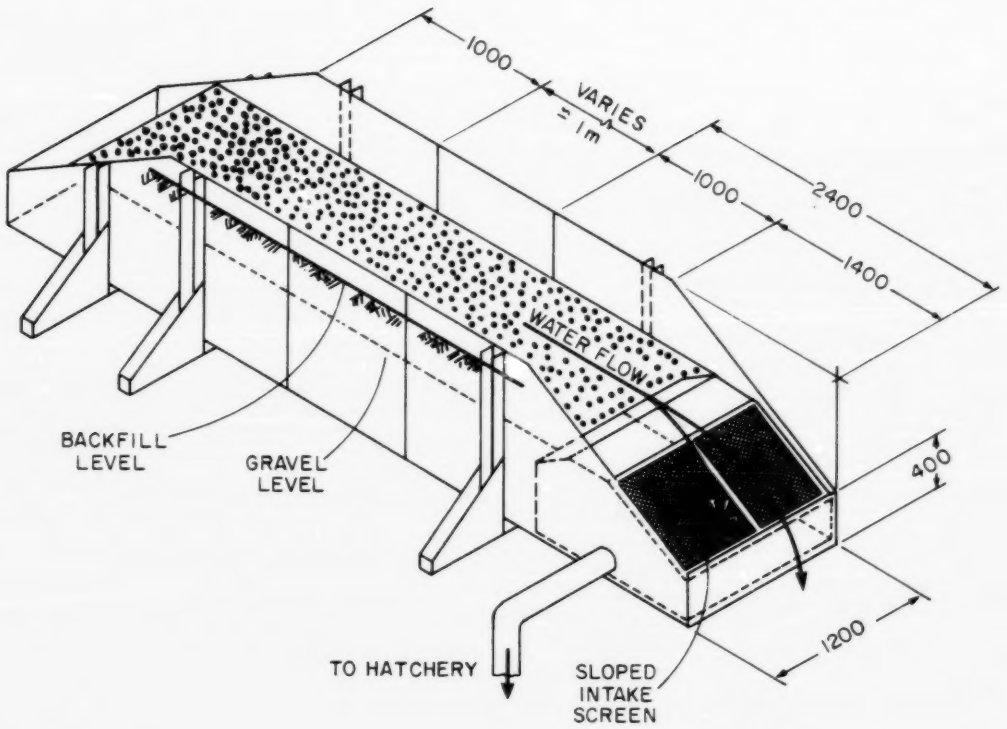
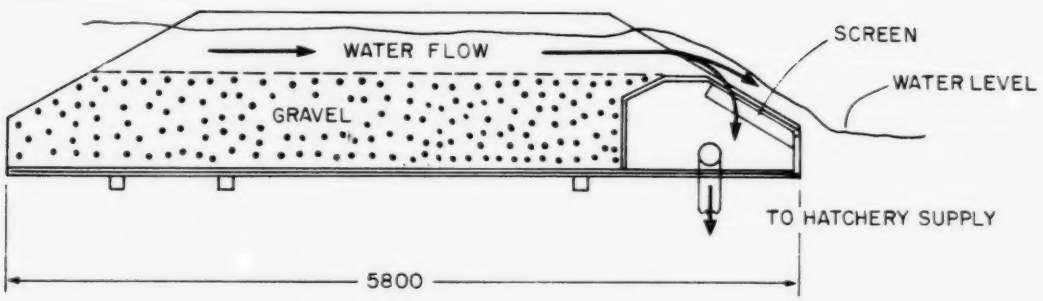


Figure 2 Kalum Pilot : General Layout



500 0 500 1000 mm

Dimensions in mm



SIDE VIEW

Figure 3 Intake Structure for Kalum Pilot Hatchery

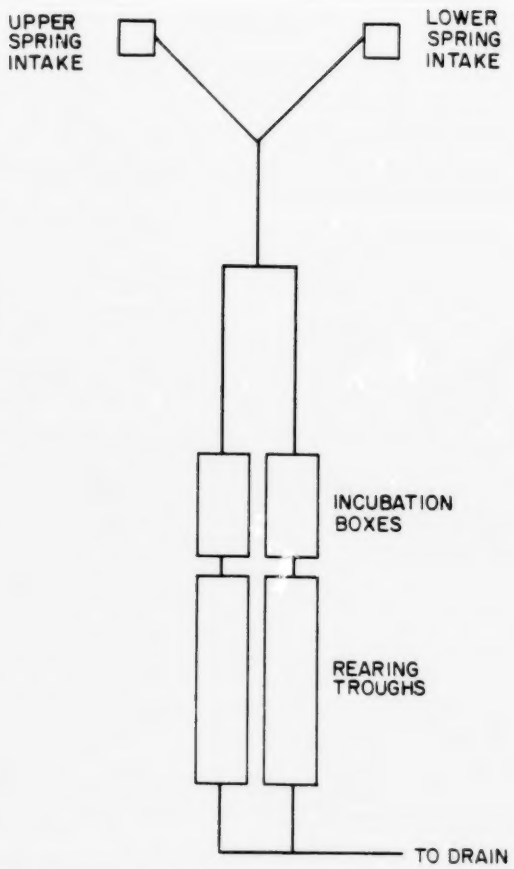


Figure 4 Schematic Layout of Kalum Pilot I Facilities

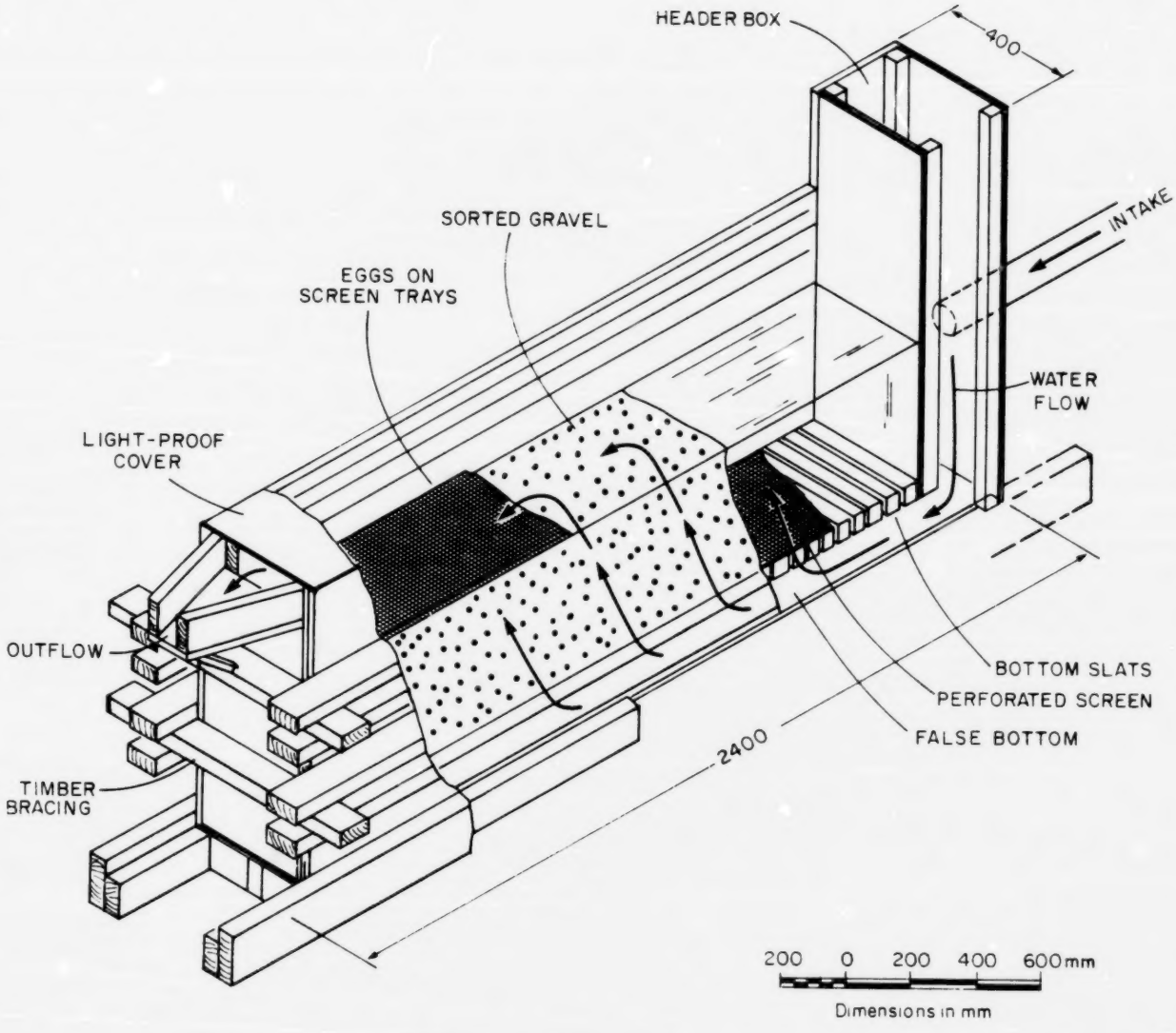
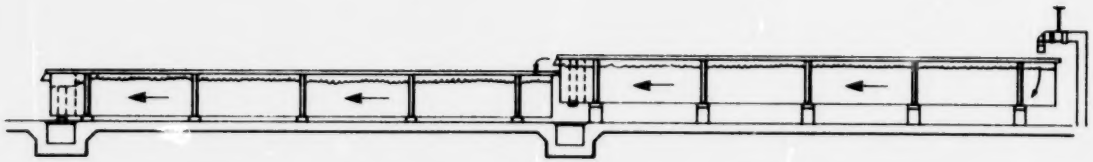


Figure 5 Upwelling Incubation Box



SIDE VIEW OF ARRANGEMENT

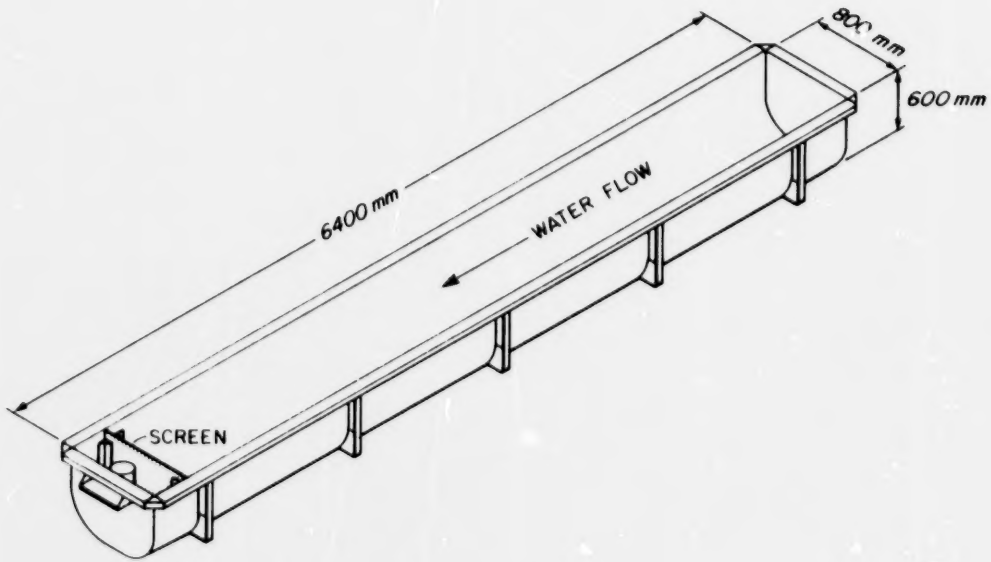


Figure 6 Capilano Style Rearing Trough

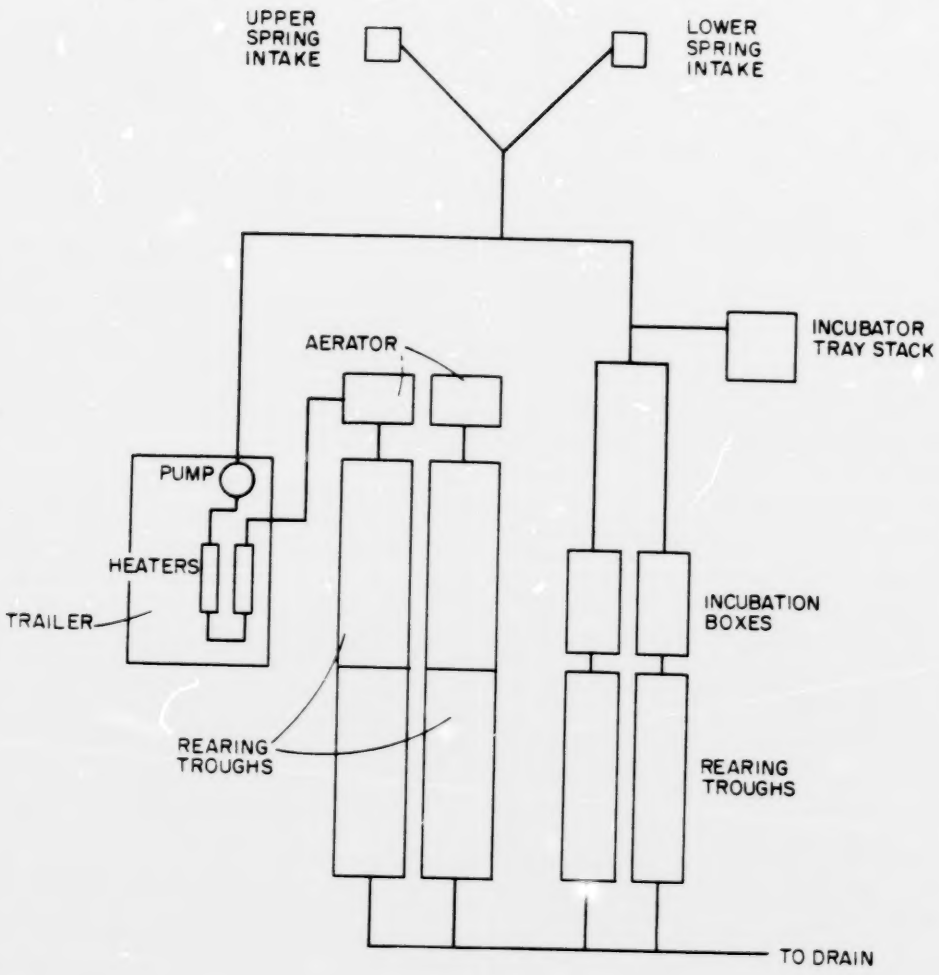
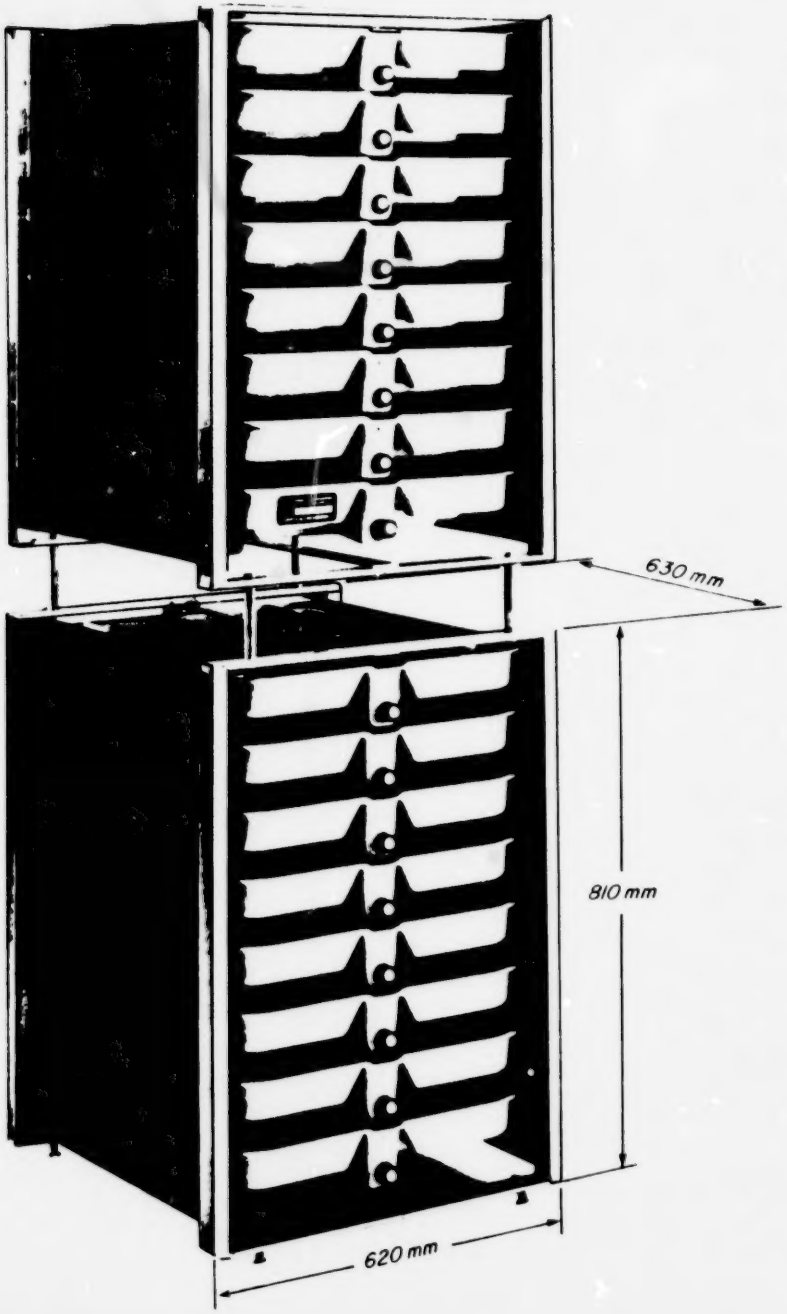


Figure 7 Schematic Layout of Kalum Pilot II Facilities



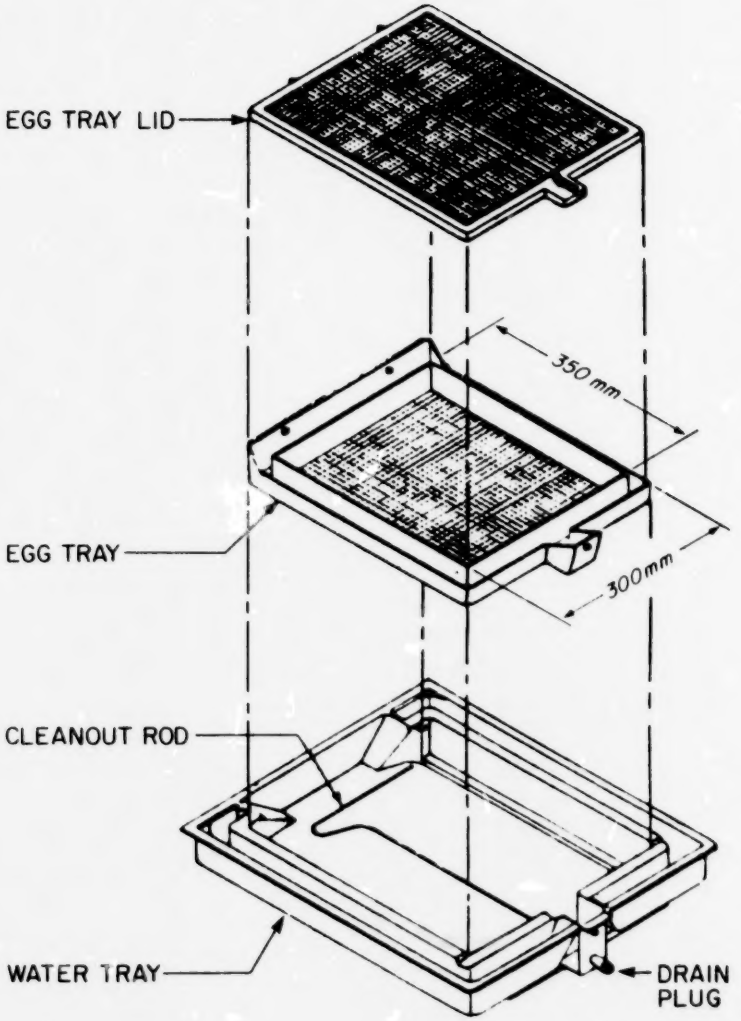


Figure 8 Vertical Incubator and Assembly

troughs. Two additional troughs were installed in the outlet to the beaver pond, to experiment with utilizing water from the pond (which was presumed to have received some solar heating) for rearing. A floating, skimmer type, gravity feed intake was placed in the beaver pond to provide about 120 LPM each to the two troughs through a 50 mm diameter PVC line.

A cascading aeration device (Figure 9) was installed in the summer of 1981 just below the gabion dam to improve the dissolved gas characteristics of the water. The aerator was made up of a 96 cm high x 45 cm wide x 122 cm long wooden support cage containing nine 122 cm x 45 cm expanded aluminum mesh screens on wooden frames.

Two industrial electric water heaters were installed in a small ATCO trailer on the site and a 40 KW diesel generator was located nearby. Each heater was rated to be able to heat a water flow of 114 LPM by 2°C. The heaters were plumbed to two 200 mm diameter, eight-segment, packed column aerators (Figure 10) which were placed at the head of each line of new troughs to offset supersaturated nitrogen gas levels that resulted from both ambient and heated water conditions.

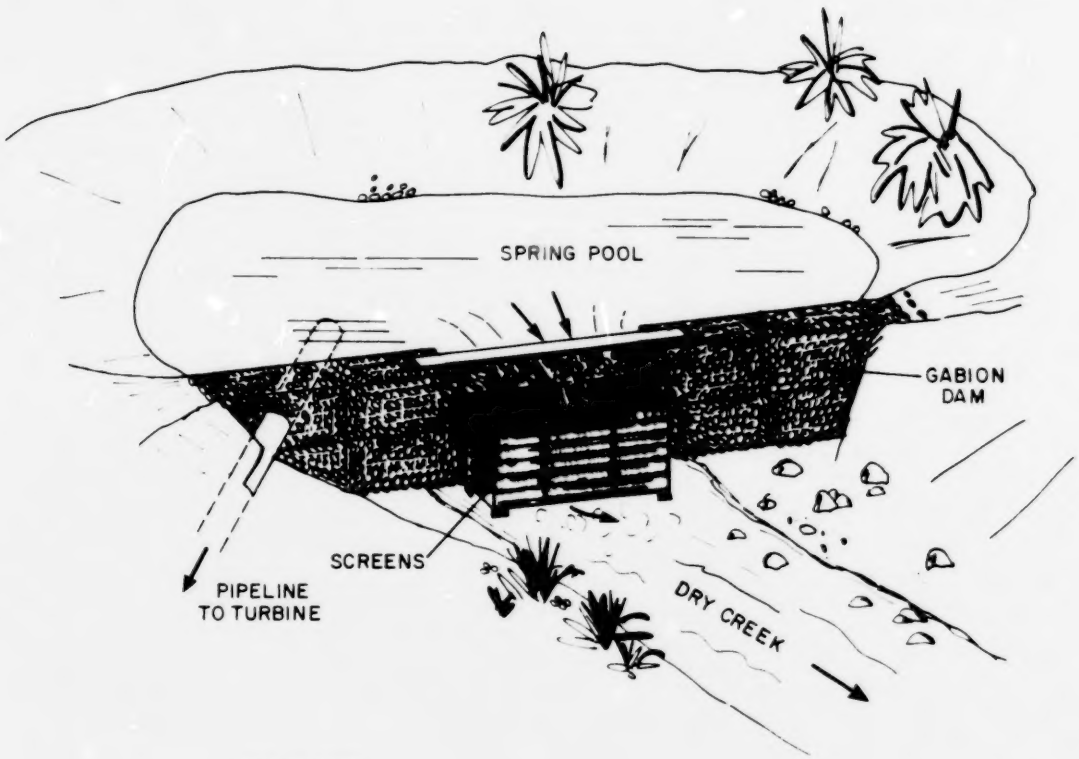
Pilot III

For Pilot III in 1982/83 (Figure 11), six more eight-tray incubator stacks and three 10-tray stacks were added to the facility, bringing the incubation capacity to 360,000 eggs. These were installed at the tail end of the Capilano trough lines, so as to take advantage of the water heating and aeration facilities already in existence.

WATER QUALITY

Water quality samples were collected from the upper spring of Dry Creek and from nearby Clear Creek on 10 occasions between November 1978 to November 1980. Additional samples were collected on several occasions from the lower spring of Dry Creek.

The samples were collected according to the methods outlined in MacKinlay (1984). Temperature and pH were taken *in situ* by handheld thermometer and Hach kit at the time of sampling. The samples were packed on ice and delivered by air within 48 hours to the Department of Fisheries and Oceans (DFO) - Environment Protection Service (EPS) Laboratory in West Vancouver for analysis. Sample analysis followed the methods outlined in Environmental Protection Service (1979).



Not to scale

Figure 9 Screen Box Cascade Aerator at Gambion Dam at Kalum Pilot Hatchery

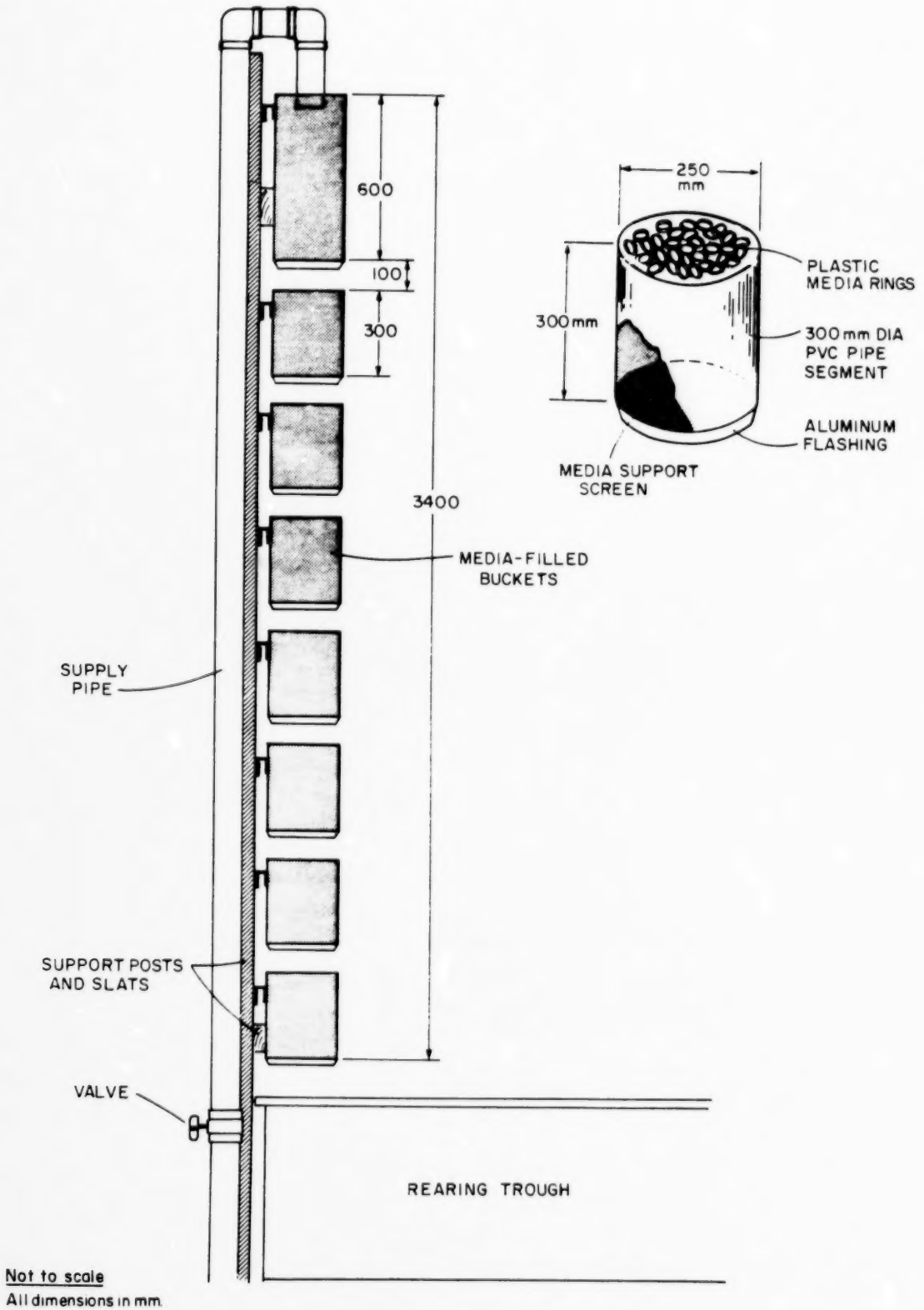


Figure 10 Packed Column Aerator at Kalum Pilot Hatchery

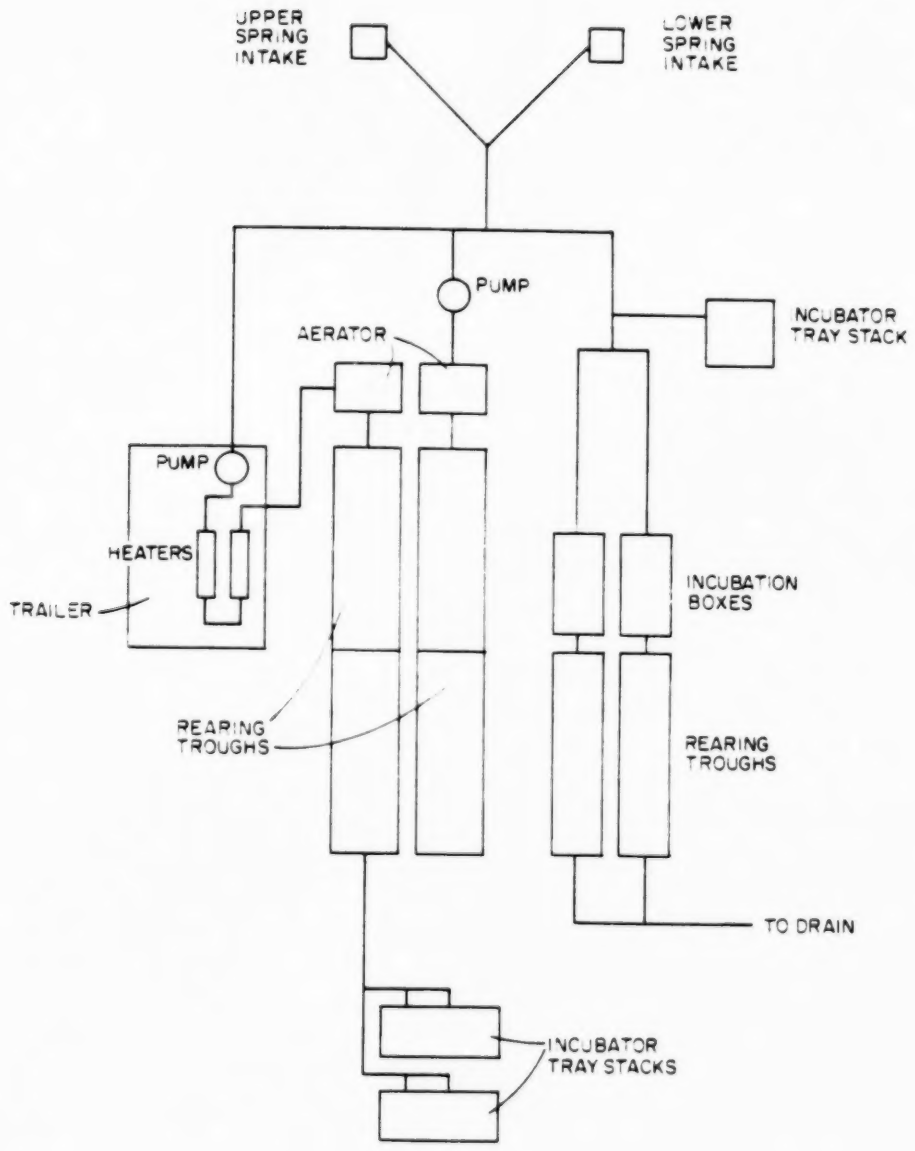


Figure 11 Schematic Layout of Kalum Pilot III Facilities

Total gas pressures were measured with a Novatech Model 300B tensiometer calibrated with a sphygmomanometer. Dissolved oxygen was measured with a Hach field kit, which is a modification of the Winkler titration method (APHA et al., 1980). Barometric pressure was measured using a Thommen model 2000 pocket altimeter at the time of each tensiometer reading. These measurements were used to determine the percent saturation of total gases, oxygen and nitrogen (Colt, 1984). Gas pressure was measured twice before the start up of the hatchery and a number of times throughout the operation of the Pilots.

Clear Creek and Dry Creek water temperatures were monitored with Peabody-Ryan J-180 thermographs from August 1979 to July 1980. Temperatures at the Dry Creek springs were measured using pocket thermometers during the periods of manned pilot hatchery operation.

Rearing trough temperatures were monitored daily with a Taylor maximum-minimum thermometer located at the outlet. Dissolved oxygen in the troughs was measured at the outlets once a week with a YSI oxygen meter or with a Hach kit.

ADULT COLLECTION AND EGG TAKE

Broodstock were generally collected during the earlier portion of the spawning runs by drifting 13.3 cm opening-sized gillnets through schools of spawning or holding adults. Adults that were not mature when caught were placed in 2.4 m wide x 2.4 m long x 1.2 m high mesh covered net pens to ripen.

Adults in the pens were periodically tested for ripeness after being anaesthetized in a 0.02% 2-phenoxyethanol bath. If some of the females were ripe, sperm was milked first from the live males into dry jars. Special attention was made to avoid mixing any water in with the sperm. The jars were then capped and placed on ice. Ripe females were then killed with a blow to the head, the gills were cut and the fish were hung upside down to bleed. After being wiped dry, the fish were held over a dry plastic bucket and the eggs were gently spilled into the bucket from an incision made from the ovipositer to the anterior end of the body cavity. The buckets of eggs were sealed, placed on ice and transported to the hatchery site.

INCUBATION

At the hatchery site the eggs were poured into a plastic basin and the milt from at least two males for every female was stirred in by hand. Water was added, then the mixture was allowed to stand for 2 - 3 min before being poured onto the screens of the gravel incubators or the incubator trays. Each incubation box tray was filled with approximately 38,000 eggs (two trays per box) and each incubator tray was filled with 5,000 eggs (eight trays per stack). Flows were set at 35 LPM per incubation box and 11.5 LPM per incubator tray stack.

Six 100 mL samples of eggs were taken and counted to determine the number of eggs per liter. The volume of eggs was then measured and converted to the total number taken. This method of estimation was only an approximation because of the ovarian fluid included in with the eggs. A more accurate estimate of egg numbers was obtained by volumetric counting during the first egg-pick after the eggs had reached the eyed stage.

The 1980 brood was incubated in the two gravel incubation boxes. The 1981 brood was split 50/50 between the gravel incubation boxes and the stacks of tray incubators (Figure 6). The 1982 brood stock was incubated in tray stacks only. In 1982, half of the eggs collected from Cedar River and Clear Creek and all of the eggs from the lower Kitsumkalum River were incubated in water heated 3 - 4°C above ambient temperatures after November 27.

After the eggs had at least 300 accumulated thermal units (ATU in °C days) and were eyed, they were shocked by pouring them into 5 cm of water from a height of 0.6 - 1.0 m. After shocking, the eggs were placed back in their incubation units for 12 - 24 hrs before the dead eggs were picked out with blunt forceps. At this time six 100 mL samples of eggs were counted so that the numbers of eggs could be more accurately estimated. The numbers of dead and live eggs were estimated separately. Representative samples of dead eggs were cleared in Stockard's solution to determine the fertilization rate.

REARING

When the fry began to emerge from the incubation boxes, or were 80 - 90% swim-up stage in the tray incubators, they were crowded into the top third of the Capilano rearing troughs to initiate feeding. Once a week before the first morning feeding, three 450 g samples of fry were counted. A sub-sample of 30 fry was anaesthetized in 2-phenoxyethanol (0.4 mL/L), blotted dry with paper

towels, weighed to the nearest 0.01 g and measured for nose-fork length measured to the nearest millimeter.

Initially, the flow to each rearing trough was set at 40 LPM, then increased as the numbers and size of fry increased. The flows were measured daily using the bucket and stopwatch method.

TAGGING

Chinook fry produced during the three years of pilot operation were tagged with binary-coded wire nose tags (CWT) and adipose fin clipped to help future evaluation of adult distribution, migration routes, contribution to the various fisheries and survival rates post-release.

Tagging was carried out at the end of each rearing program just prior to release. The fry were first anaesthetized with tricaine methane sulphonate (MS 222), then finclipped and tagged. Post-tagging mortalities and tag retention were checked by holding the fry for 24 - 48 hrs prior to release and passing samples of 100 fry through the quality control device for a second time. The juveniles were then returned to the areas where their parents had been captured. The 1980 brood from the lower Kitsumkalum was released 1.5 km below Treston Lake, a southern expansion of Kitsumkalum Lake. The 1981 brood releases from the Cedar/Clear systems were split between the Little Cedar River and Clear Creek. The lower Kitsumkalum brood were released into the lower Kitsumkalum River 5 km below Treston Lake. The 1982 Cedar/Clear brood was released at the bridge near the Nass River Road junction. The lower Kitsumkalum brood were released at Redsand Lake.

TAG RECOVERY

Preliminary data on the recovery of Kalum Pilot tags from adult salmon was obtained from two sources: the Mark Recovery Program (MRP) data base for tags recovered in the various commercial and sport fisheries and; from a DFO Salmon Services adult escapement study done on the Kitsumkalum in 1985 and 1986 (Andrew and Webb, 1987).

The MRP data comes from proportional sampling of all the commercial fisheries on the Pacific coast, from Alaska to California (Bailey et al., 1984). Each fish with an adipose fin clip has its head dissected to obtain the coded wire tag

embedded in its nose cartilage. The number of tags of each particular code actually "observed" is divided by the sampling rate to give the number of tags "estimated" to have been caught. For most tagged groups, the "estimated" value is divided by the tagged-to-total released ratio to give an "expanded" estimate of tag recoveries. However, since most of the Kalum Pilot untagged releases were fish too small to tag, and therefore presumably less fit to survive, only the "observed" and "estimated" tag recoveries were used for this report. The recovery data used was drawn from the MRP data base in 1987, and includes all recoveries recorded for the Kalum Pilot tag groups up to and including the 1986 fisheries.

The escapement study in 1985 and 1986 used the Petersen tag-and-recapture method to estimate the escapement to the Kitsumkalum River below Kitsumkalum Lake. The upper river stocks, including the Cedar and Clear stocks used in the Kalum Pilot Hatchery, were not enumerated in detail. Prior to the onset of spawning, about 1,500 chinook adults were seined out of the lower river, tagged with spaghetti or disk tags and released where they were caught. Following spawning, a dead pitch program inspected about 1,500 carcasses for the presence of tags and used the Petersen formula to estimate total population size. During both the seining and dead pitch operations, the heads of fish with adipose fin clips were removed for dissection and rearing of the coded wire tags embedded in the nose cartilage. These "observed" recoveries for each tag group and year were divided by the sampling rate to give the "estimated" tag recoveries from the escapement (Andrew and Webb, 1987).

RESULTS

WATER QUALITY

Laboratory Analyses

The results of the water quality tests by the DFO/EPS laboratory collected from Dry Creek (Table 1) revealed some high readings for nitrate and mercury which were considered to be due to sample contamination. Aside from these anomalous readings, all the parameters were well within the acceptable limits for fish culture outlined by Sigma (1983). The water from Dry Creek can be characterized as being extremely clean, relatively soft water, of excellent quality for salmonid culture.

Table 1. Water Quality of Dry Creek

Parameter	Units	Recommended Limits	Nov. 20 1978	Jan. 11 1979	Feb. 12 1979	Apr. 19 1979	May 15 1979	Jul. 11 1979	Aug. 30 1979	Nov. 26 1979	Apr. 15 1980	Jul. 15 1980
Alkalinity	mg/L	20-300	38.0	34.9	34.1	37.0	37.0	35.1	31.4	34.7	35.5	32.7
Conductivity	umho/cm	150-2000	95	88	90	93.9	92.8	81.5	81.3	99.5	95.8	81.0
Diss. Oxygen	mg/L	>6-8	9.0	10.3	-	-	10.0	-	-	-	-	8.5
Diss. Oxygen	% sat.	100%	74.4	85.1	-	-	79.0	-	-	-	-	65.6
Diss. Tot. Gas	% sat.	<103%	102	-	-	-	-	-	-	-	-	-
Diss. Nitrogen	% sat.	<102%	110.3	-	-	-	-	-	-	-	-	-
Hardness	mg/L	20-400	43	-	47.6	40.2	41.2	37.8	37.2	41.3	40.0	34.8
Nitrate	mg/L	<.12	.078	-	.083	.085	.105	-	.036	.088	.129	.101
Nitrite	mg/L	<.012	0	0	0	0	0	0	0	0	.0089	0
pH-field	units	6.8-8.5	-	-	9	-	-	-	7.0	-	7.0	7.0
pH-lab	units	6.8-8.5	6.8	7.1	7.3	7.2	7.2	7.3	7.1	7.3	7.2	7.1
Phosphate	mg/L	<.05	0	0	0	0	0	0	0	0	0	0
Res-filterable	mg/L	70-400	60	59	59	64	64	57	53	62	65	55
Res-nonfilt	mg/L	<3	0	0	0	0	0	0	0	0	0	0
Silica	mg/L	10-60	2.54	2.55	2.55	-	2.45	2.58	2.50	2.78	2.48	2.29
Sulphate	mg/L	<90	8.5	9.05	9.55	8.96	7.65	6.22	8.18	11.2	9.6	7.3
Taste		OK	OK	OK	-	OK	OK	-	-	-	OK	OK
Temperature	°C	4-18	6.0	6.0	5.2	4.0	4.0	4.0	4.5	6.5	4.5	4.5
METALS												
Ca-Calcium	mg/L	4-150	15.0	14.4	15.5	14.4	14.7	13.3	13.1	14.5	14.4	10.7
Cd-Cadmium	mg/L	<0004	0	0	0	0	0	0	0	0	0	0
Cr-Chromium	mg/L	<.01	0	0	0	0	0	0	0	0	0	0
Cu-Copper	mg/L	<.006	0	0	0	0	0	0	.0032	0	0	0
Fe-Iron	mg/L	<.03	0	0	0	0	0	0	0	0	0	.068
Hg-Mercury	mg/L	<.00005	0	0	0	0	0	0	0	0	0	.00068
K-Potassium	mg/L	<50	.152	.145	.136	.136	.137	.123	.133	.156	.146	.123
Mg-Magnesium	mg/L	<10	1.23	1.22	1.28	1.08	1.08	1.11	1.09	1.23	0.98	0.88
Mn-Manganese	mg/L	<.05	0	0	0	0	0	0	0	0	0	0
Na-Sodium	mg/L	<500	1.2	1.17	1.23	1.24	1.19	1.35	1.48	1.66	1.43	0.91
Pb-Lead	mg/L	<.01	0	0	0	0	0	0	0	0	0	0
Si-Silicon	mg/L	<60	2.2	2.51	2.34	2.13	2.45	2.43	2.47	1.97	2.26	2.16
Zn-Zinc	mg/L	<.005	0	0	0	0	0	0	0	0	0	0

Note - Zero (0) indicates a value below the laboratory detection limit; underlined values are outside recommended limits.

Temperature

Water temperatures were measured in Dry Creek when water samples were taken from November 20, 1978 to July 15, 1980 and by thermograph from August, 1979 to July, 1980 (Table 2). Dry Creek was relatively warm (5-7°C) for incubation during the winter and fall months, which would advance egg development and result in early fry emergence. After emergence in January and February, temperatures in Dry Creek decreased to approximately 4.5°C by June, indicating that rearing temperatures might be too cold. In the years that the pilot was in operation, temperatures generally followed the same pattern as those recorded during the 1978-80 reconnaissance period, but were slightly warmer than the 1979/80 temperatures by approximately 1°C from February to May in 1981, 1982 and 1983. The detailed temperature records for this period have unfortunately been lost. Temperatures recorded by handheld thermometer from January to February in 1978 were approximately 1°C cooler than in 1979. These differences may have been artifacts of the relatively poor precision of the thermometers and thermographs used ($\pm$ at least 0.5°C).

Temperatures in the beaver pond on Dry Creek below the hatchery site were monitored during the hatchery operation in 1982, to determine if solar heating increased the temperatures above those of the two springs. Mean daily temperatures in the beaver pond, measured from the end of March to early May, did not exceed those of the hatchery supply by more than 1.0°C.

Gas Pressures

Gas pressure measurements, made at the upper spring between November 20, 1978 and February 11, 1983, were quite variable (Table 3). Total gas pressure varied from 95.5% to 106.3% of saturation, with partial pressure of nitrogen (with argon) varying between 102.1% to 111.2% and oxygen pressure varying between 65.6% to 112.7% of saturation. Measurements of total gas pressure on three occasions exceeded the generally accepted safe level of 103% (Sigma, 1983). Nitrogen gas pressure always exceeded the maximum safe criteria of 102%. Oxygen was generally undersaturated, but sufficient for fish culture at reduced loadings.

The addition of the cascade aerator in July 1981 reduced the nitrogen level, and increased the concentration of oxygen. Measurements on August 4, 1981 indicated that nitrogen fell from 103.7% to 101.8% of saturation and oxygen increased from 87.0% to 95.4% after passing through the aerator. The total gas pressure increased slightly from 100.1% to 100.4%. Although measurements directly below

Table 2. Monthly Mean Temperatures for Dry Creek

Month	1979	1980	1981	1982
Jan		6.7	7	
Feb		6.2	6.1	6.1
Mar		-	5.5	5.9
Apr		5.6	5.0	5.5
May		4.7	4.6	
Jun		4.5		
Jul		4.7		
Aug				
Sep	5.3	5.5		
Oct	6.0	6.0		
Nov	6.5	6.3		
Dec	6.8	6.6		

Data for Sept. 1979 to July 1980 from MacKinlay (1984).

Table 3. Gas Pressure Measurements at the Kalum Pilot.
(in percent of saturation)

Date (location)	TGP(%)	N_2+Ar(%)	O_2(%)	Temp.(°C)
Nov 20/78 (upper spring)	102.0	110.3	74.4	6.0
Jan 11/79 (upper spring)			85.1	4.0
May 15/79 (upper spring)			79.0	4.5
July 15/80 (upper spring)			65.6	5.0
Aug 26/80 (upper spring)	95.5	103.4	65.9	4.6
Jan 13/81 (trough 1)	101.9-102.0	102.1-103.2	97.8-101.1	
Apr /81 (trough1)	105.3	110.9	84.3	
July 14/81 (upper spring)	102.5	110.0	70.5	4.6
Aug 4/81 (above waterfall aerator)	100.1	103.7	87.0	
Aug 4/81 (below waterfall aerator)	100.4	101.8	95.4	
Aug 4/81 (incubation box header)	100.7	104.1	87.9	
May 10/82 (above waterfall aerator)	106.3	104.7	112.7	
May 10/82 (heated water)	100.7	97.1	114.5	
Feb 11/83 (upper spring)	104.1	111.2		
Feb 11/83 (heated water)	101.5	104	92.4	8.2
Feb 17/83 (unheated trough)	100.9	102.8	96.0	6.0
Mar 15/83 (heated trough)	101.3	104.7	102.6	7.6
Mar 1/83 (heated trough)	100.7	103.1	92.4	8.0

the aeration device were more favourable, measurements at the incubation header box indicated gas levels similar to that above the aerator. All the gas pressure measurements at the hatchery facilities subsequent to the installation of the cascade aerator were below 102%.

After the installation of the water heaters and packed column aerators in late 1981, total gas pressures measured in the heated troughs varied between 100.7% and 101.5%, nitrogen concentration varied between 97.1% and 104.7%, and oxygen concentration varied between 92.4% and 114.5%. Measurements on February 11, 1983 indicated that the combination of the cascade and packed column aerators reduced the total gas pressure from 104.1% to 101.5% and reduced the nitrogen pressure from 111.2% to 104.1%.

The addition of the aeration devices improved the gas pressures, however, the nitrogen and total gas pressures were still at slightly supersaturated levels.

ADULT COLLECTION AND EGG TAKE

Egg takes for all three years are summarized in Tables 4 and 5.

Pilot I

From August 25 to September 9, 1980, a total of 18 male and 12 female chinook adults were captured and used as donor stock for the hatchery. No females were lost due to holding mortalities. Approximately 100,000 eggs were estimated to have been taken. The estimate was adjusted to 87,000 when the eggs were picked on November 4.

Pilot II

During helicopter reconnaissance of the Cedar River on July 23, 1982, 62 chinook salmon were observed, many of them actively spawning. On July 26, donor stock acquisition was started and 7 males and 3 females were captured. The holding pens were subsequently damaged by humans or animals, allowing all of the fish to escape. More donor stock was acquired by drifting tangle nets over the spawning grounds in the Cedar River and Clear Creek. Approximately 66,000 eggs were taken (Table 5). Of these, 60% were placed in vertical incubator trays and 40% were placed on screens in one of the gravel incubators.

Table 4. Summary of lower Kitsumkalum River egg takes 1980 - 1982

Date	Females Spawned	Males Spawned	Volume of Eggs (L)	Estimated Number of Eggs
1980				
Aug 31	1	3	2.225	6,609
Sept 2	4	4	8.525	26,513
4	1	4	2.700	8,640
6	2	4	5.325	16,561
8	3	3	8.600	27,058
9	1	3	2.950	9,175
10	1	3	1.100	3,421
Total	12			97,977*
1981				
Aug 30	3	6	6.575	16,438
Sept 1	5	5	12.750	13,875
2	10	7	30.850	77,125
3	4	5	10.500	26,250
Total	22		60.675	151,688**
1982				
Sept 1-2	11	19	31.0	77,500

* reestimated at 87,000 eggs on Nov. 4.

** reestimated at 146,000 eggs on Nov. 4.

Table 5. Summary of Cedar River and Clear Creek egg takes 1981 - 1982

Date	Females Spawned	Males Spawned	Volume of Eggs (L)	Estimated number of eggs
CLEAR CREEK 1981				
Aug 1	1	ND	1.300	4,650
3	2	ND	1.875	5,813
4	1	ND	2.200	6,820
6	2	ND	4.825	15,322
7	2	ND	3.175	9,843
CEDAR RIVER 1981				
Aug 2	1	ND	1.375	4,263
3	2	ND	2.075	6,433
4	1	ND	2,500	7,750
5	2	ND	3.400	10,540
Total			22.925	71,020*
CLEAR CREEK 1982				
July 27	1	1	1.10	3,377
29	3	3	7.40	22,718
31	1	1	2.70	8,289
Aug 1	1	1	1.50	4,605
2	1	2	2.70	8,289
3	1	1	2.30	7,061
4	1	1	1.15	3,531
6	1	2	0.70	2,149
Total	10		19.55	60,019
CEDAR RIVER 1982				
July 20	1	2	2.50	7,675
22	1	2	2.65	8,131
24	1	1	2.00	6,140
26	2	2	5.46	16,762
27	1	3	2.55	7,675
Aug 1	1	2	1.30	3,991
3	1	2	2.85	8,750
4	1	2	0.90	2,763
5	1	1	3.10	9,517
8	1	3	2.50	7,675
Total	11		25.81	79,237

*-reestimated at 66,000 on October 7.
ND-No data

The lower Kitsumkalum egg take was conducted between August 30 and September 4. Approximately 146,000 eggs were taken from 22 females and sperm was collected from 23 males.

Pilot III

Adult collection and egg take activities started six days earlier on the Cedar River in 1982 than in 1981; running from July 20 to August 8. A higher number of adults were obtained (20 males and 21 females), but there were high losses of holding fish, so only approximately 79,000 eggs were obtained from 11 females (Table 5). In Clear Creek 60,000 eggs were taken from 10 females with no holding losses. The lower Kitsumkalum River egg-take was conducted on September 1 and 2, using 19 males and 11 females, from which 83,000 eggs were taken. The adults were ripe enough when captured, thus holding was not required.

INCUBATION

Pilot I

Survival to the eyed stage was relatively poor at 77.3%, or 66,738 of the total 87,349 eggs taken in 1980 (Table 6). A test of fertilization indicated that only 82% of the total eggs laid down had been successfully fertilized. A fungus problem developed in one of the incubation boxes. However, over 64,000 fry emerged, so mortality (2.9%) from the eyed stage was not substantial. This represented a 96.3% eyed egg to fry survival, and an overall survival of 74.4% from planting to emergence.

Pilot II

All of the 146,000 eggs collected in 1981 began incubation on screens in the gravel incubators. The Cedar and Clear brood had a combined survival of 96.5% to the eyed stage when they were picked on October 7 (Table 7). The lower Kitsumkalum brood had a similar survival of 93.3% when picked on November 4.

After the eggs were picked, all of the brood from the Cedar and Clear systems were transferred to incubator trays, while all of the eggs from the lower Kitsumkalum system were incubated in the gravel boxes. Survival from egg pick to emergence was only 77.5% for the lower Kitsumkalum brood, while no significant mortality was encountered between egg pick and ponding for the Clear/Cedar brood.

Table 6. Survival Summary for the 1980 Brood at the Kalum Pilot.

Inventory Item	Kitsumkalum R. Stock
Eggs taken	86,349
Eyed Eggs	66,738
Survival to Eyed	77.3%
Fry Ponded	64,268
Eyed-to-Ponded Survival	96.3%
Incubation Survival	74.4%
Fry Released	
Marked	44,580
Unmarked	18,842
Total	63,422
Rearing Survival	98.6%
Survival Egg-to-Release	73.1%

Table 7. Survival Summary for the 1980 Brood at the Kalum Pilot.

Inventory Item	Kitsumkalum R. Stock	Cedar/Clear R. Stocks		Total
Egg taken	146,000	66,000		212,000
Eyed Eggs	136,218	63,650		199,868
Survival to Eyed	93.3%	96.5%		94.3%
		Heated	Ambient	
Fry Ponded	109,569	30,364	32,396	172,599
Eyed-to-Ponded Survival	80.4%	98.6%		86.4%
Incubation Survival	77.5%	95.1%		81.4%
Fry Released				
Marked	53,226	18,937	16,204	88,367
Unmarked	51,424	9,063	12,596	73,083
Total	104,650	28,000	28,800	161,450
Rearing Survival	95.5%	92.2%	88.9%	93.5%
Survival Egg-to-Release	71.7%	86.1%		76.2%

Pilot III

Clear and Cedar eyed eggs were picked between October 4-8, 1982, showing a poor survival of 75.6% (Table 8). Lower Kitsumkalum eggs were picked November 5-6 with a survival of 85.5%. On November 27, the eggs from the Clear and Cedar systems were divided into two lots. One lot was incubated in heated water and the other in unheated water. All of the lower Kitsumkalum eggs were incubated in heated water after November 27. Survival from planting to emergence was 77.4% for the three groups, all incubated in vertical trays.

REARING

Pilot I

Fry emerged from the incubation boxes from late January to mid April of 1981 (Table 9). Peak emergence occurred on February 23, having attained 1017 ATU since September 6, the day that 50% of the eggs had been fertilized.

Up until February 26, all the fry were crowded into one trough to promote feeding. Feeding was started on February 4. At the outset of feeding the fry were fed Biodiet and OMP on alternate days since the initial strategy was to compare starter diets. The amount of OMP fed followed Stauffer's (1973) feed formula recommendations. The pellet size and frequency of feeding followed the OMP manufacturer's feeding chart. Biodiet was fed to 7/8 of the rate used for OMP, to compensate for the reduced moisture content of Biodiet. It was noticed that the Biodiet contained an unacceptable amount of "sawdust", so after several days, the use of Biodiet was discontinued and only OMP was fed to the fry for the rest of the program.

Some of the fish showed signs of poor health at ponding. The symptoms were: bluish marks on the back of the head; frayed pectoral and dorsal fins; pale, clubbed gills; and pinheads. These symptoms were consistent with those of fish having chronic low temperature furunculosis. Between March 11 and 21, sulfamethazine was added to the food daily at a rate of 0.011 g/kg of fish as a treatment. The fish showed no improvement and there was no decrease in the mortalities. Samples of fry were sent to the DFO Disease Diagnostics Service at the Pacific Biological Station in Nanaimo but no infectious agents were detected. It was then hypothesized that the symptoms could have been the result of overcrowding at the onset of feeding, or from coagulated yolk sac disease that was noticed in some of the eggs during picking. Potassium permanganate ($KMnO_4$) was applied at 1-2 ppm for two days and the density of the fish was

Table 8. Survival Summary for the 1982 Brood at the Kalum Pilot.

Inventory Item	Kitsumkalum R. Stock	Cedar/Clear R. Stocks		Total
Egg taken	83,150	126,150		209,300
Eyed Eggs	71,100	95,399		166,499
Survival to Eyed	85.5%	75.6%		79.6%
		Heated	Ambient	
Fry Ponded	67,150	48,755	46,044	161,949
Eyed-to-Ponded Survival	94.4%	99.4%		97.3%
Incubation Survival	80.8%	75.1%		77.4%
Fry Released				
Marked		32,920	24,240	57,160
Unmarked	58,817	3,830	18,803	81,450
Total	58,817	39,250	43,043	141,110
Rearing Survival	87.5%	80.5%	93.5%	87.1%
Survival Egg-to-Release	70.7%	65.2%		67.4%

Table 9. Event Timing for Kalum Pilot

Brood Year/Stock	1980 Kalum	1981 Kalum	1982 Kalum	1982 Cedar/Clear	1982 Cedar/Clear
Adult Collection and Egg Takes	Aug 25 - Sep 9	Aug 30 - Sep 4	Sep 1 - 2	Jul 26	Jul 20 - Aug 8
Eyed Egg Pick	Nov 4	Nov 4	Nov 5 - 6	Oct 7	Oct 4 - 8
Ponding/Swimup	Jan 28 - Apr 16	Feb 4 - Apr 30	Jan 10	Jan 12 - 13	Dec 27 - Jan 27 Jan 27
Release	May 25 - June 2/81	May 5 - 6/82		Apr 20 - 28/82	Apr 27 - 28/83

decreased. At the end of the first week in April there was a decrease in mortalities and the symptoms began to clear. Several weeks after the treatment, all the affected fry had regenerated their fins.

The mean growth rate shown up to mid-March as indicated by samples (Figure 12) was lower than actual growth rates because of the continual recruitment of newly emerged fry. The actual growth rate was therefore greater than indicated up until mid March. Due to sampling error, there were several instances of negative growth indicated by the samples. The estimated growth rates thus may not accurately reflect the actual growth rates. However, the estimates of growth seem to reflect the general state of the fish. There was an initial period of relatively high growth right after emergence. Growth became depressed during March and April, when disease symptoms were most prevalent, but increased again during May when the disease symptoms had cleared. A summary of survivals from planting to release is shown in Table 6.

On May 1, 1981, 5,000 fry were transferred to a pen in a beaver pond 1.0 km from the hatchery site. Unfortunately, the pen was tipped over by a bear on May 1, so growth could not be compared between the troughs and the pond. Temperatures in this beaver pond ranged from 7-9°C, or 2.5-3°C warmer than the hatchery supply.

Pilot II

The operational strategy of the pilot was changed in 1981/82 to examine the use of heated water for rearing chinook fry. All of the Cedar/Clear fry were incubated in stacks of trays which allowed them to be ponded over a period of two days, January 12 - 13, 1982. These fry were split into two groups and after a one month period of rearing in heated water to initiate feeding, one group was transferred into unheated water while the other was kept in heated water.

The lower Kitsumkalum fry were incubated in gravel boxes, and were ponded as they emerged from the boxes over a period of about three months from February 4 to April 30. The first 31,500 fry that emerged from the boxes were reared in heated water for one month and then transferred to unheated water for the remainder of the rearing program. The rest of the lower Kitsumkalum brood were ponded in groups of no more than 31,500 fry per trough as they emerged, and were reared on heated water.

The fry were fed the OMP recommended amount, feeding frequency and pellet size. Water flows to the rearing troughs were also similar to those of Pilot I.

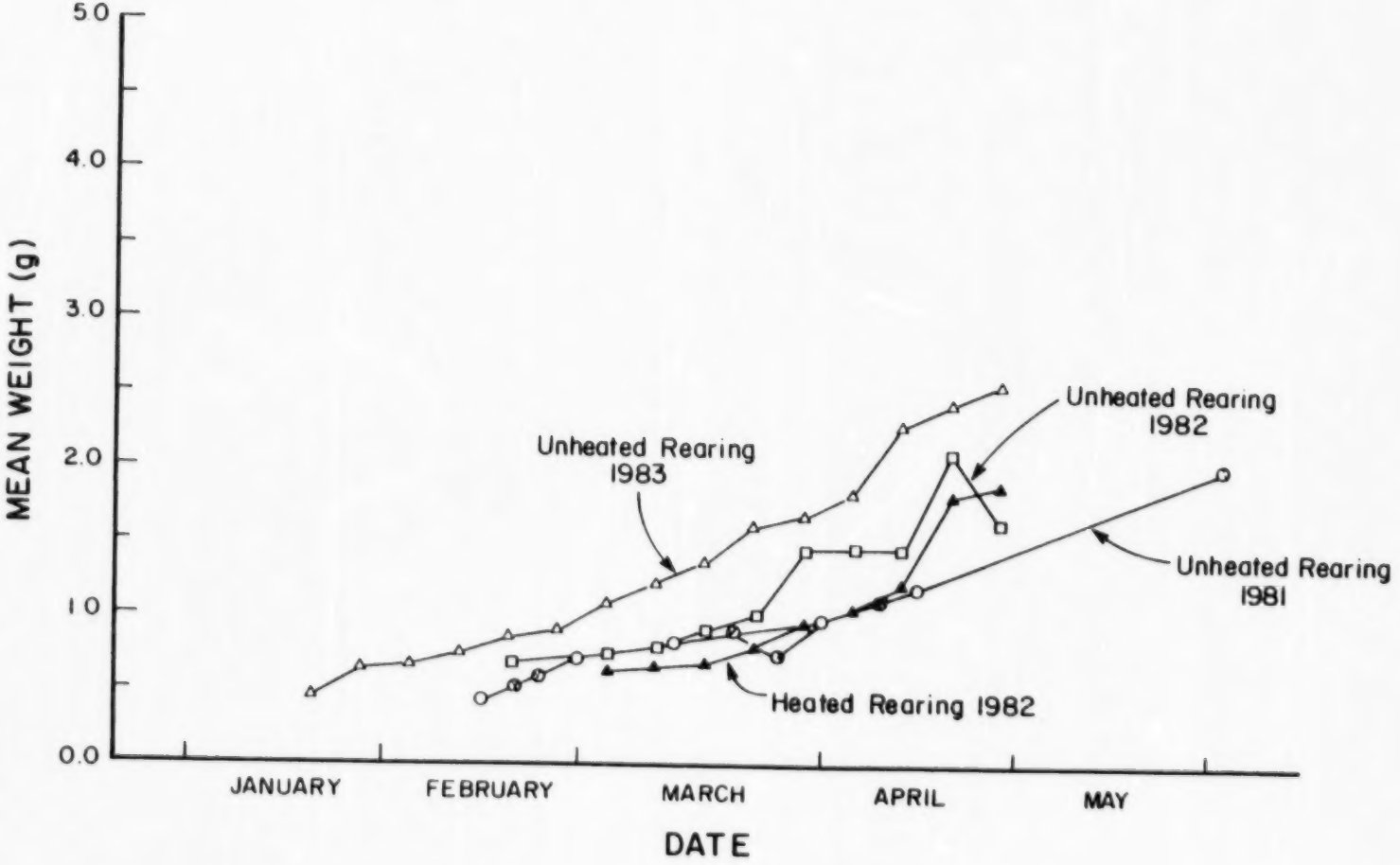


Figure 12 Growth of Kalum Stock Chinook Salmon at the Kalum Pilot Hatchery

In order to reduce heating costs, it was calculated that at least 50% of the water from the heated troughs could be safely recycled back through the heaters without causing any ill effects for the fish. Oxygen would be replenished when the water was passed back through the packed column aerators at the head of the troughs. It was calculated that up to 60% recycling could occur before the recommendation un-ionized ammonia level of 0.002 mg/L (Sigma, 1983) would be exceeded.

Water temperatures during rearing ranged from 5 - 6°C for the unheated groups and 6-7°C for the heated groups. Initially the heaters boosted the water temperature in the heated troughs by 1°C above the unheated troughs. As time progressed, the differences in temperature decreased until in April there was only an average difference of 0.4°C. The decrease in heater performance appeared to be due to clogging of the heaters with fish and food waste from the recirculation. Because of the small differences in water temperature, there was little difference between the average sizes of the groups at the time of release (Table 10, Figure 13).

The heated Cedar/Clear group weighed about 0.4 g more at release than the unheated group (Table 10). The weights of the heated Kitsumkalum groups were smaller than the unheated, because the heated groups were composed of later emergent fry and thus had shorter rearing time.

It had been planned to rear some fry in troughs supplied by water from the beaver pond beside the hatchery to test the effect of solar heated water on fry growth. The differences in water temperature between the beaver pond water and the unheated troughs were much smaller than anticipated (0.6°C in March and 0.5°C in April), so the experiment was not attempted.

During rearing, overall mortalities were 5.2%, mainly due to "drop-out" disease. The symptoms were clubbed gills and white fins. Many of the fry were released as pinheads. Samples were sent to the Diagnostic Services of the Pacific Biological Station, but no bacterial, viral or parasitic agents could be found.

Pilot III

The 1982/83 pilot operation was intended to produce 2 g and 5 g chinook fry at release, for later evaluation of survival to adults. In order to produce 5 g fry, a group of 49,000 Cedar/Clear eggs were incubated in water heated to approximately 10°C starting on November 27, to advance the date of ponding.

Table 10. Summary of chinook coded-wire tag releases from the Kalum Pilot Hatchery, 1981 - 1983

Brood Year	Stock	Total Release	Released Untagged	Released Tagged	Code Used	% Tag Retention	Average Size (g) Tagged	Average Size (g) Untagged	Release date
1980	Kitsumkalum	63,425	18,925	44,580	2/19/51	99	2.1		25/05/81-02/06/81
1981	Cedar/Clear (unheated)	28,800	12,433	16,204	2/21/49	99	3.2	0.7	27-28/4/82
	Cedar/Clear (heated)	28,000	9,063	18,937	2/23/11	99	2.7	0.9	20-22/4/82
	Kitsumkalum (unheated)	30,250	7,016	23,234	2/23/12	99	2.1	0.8	5-6/5/82
	Kitsumkalum (heated)	70,400	40,941	29,459	2/23/13	99	2.1	1.2	5-6/5/82
1982	Cedar/Clear (heated)	33,872	4,782	37,706	2/25/33	97.2	4.4		27/4/83
	Cedar/Clear (unheated)	24,987	15,318	39,555	2/25/34	97.0	2.5		28/4/83

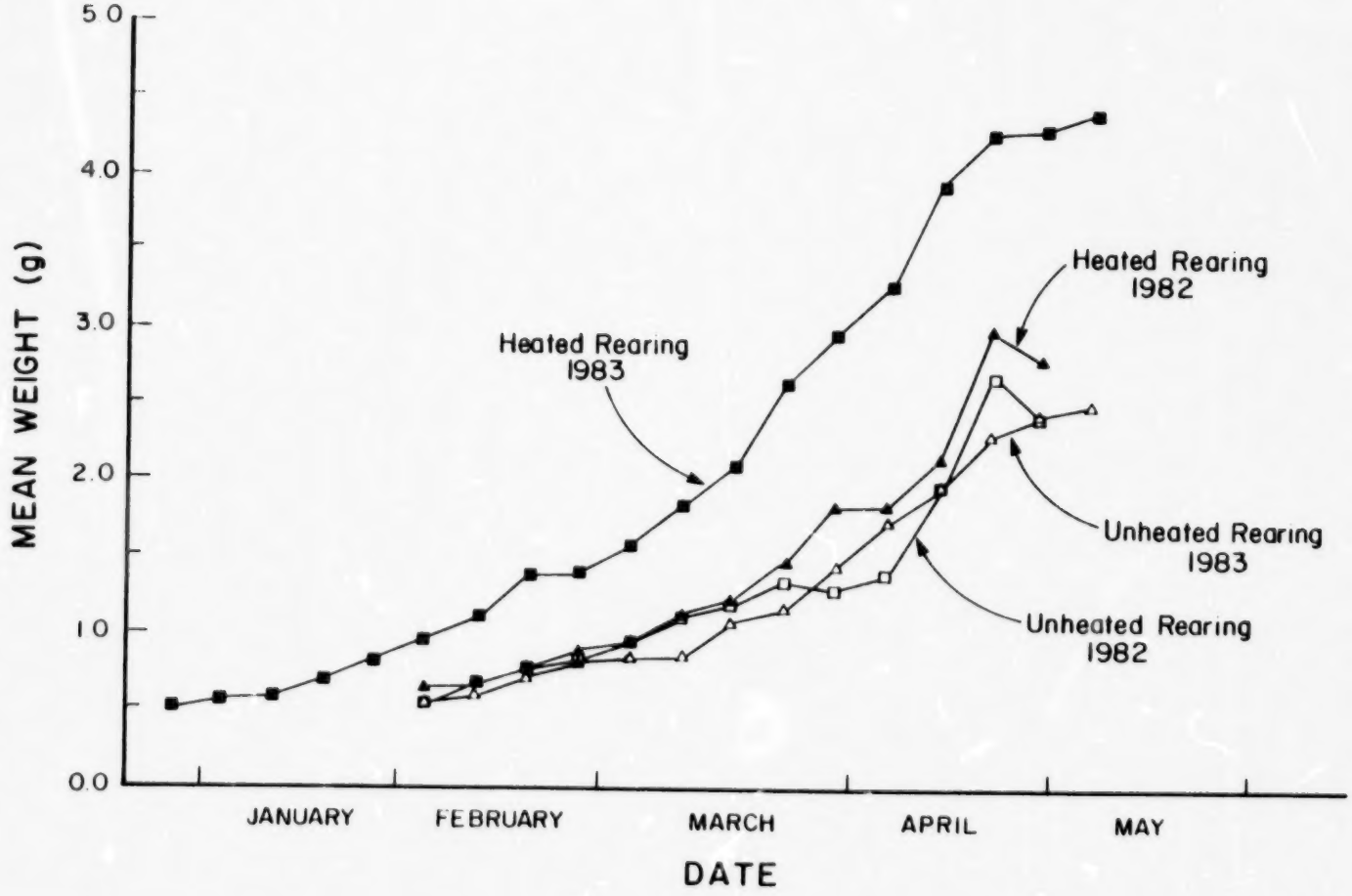


Figure 13 Growth of Cedar/Clear Stock Chinook Salmon at the Kalum Pilot Hatchery

This group was ponded on Dec 27 and reared in heated water several degrees above ambient temperature until the end of March. The remainder of the Cedar/Clear brood were ponded on Jan 27 and were incubated and reared at ambient temperatures, except for one month of heating following ponding to initiate feeding. All of the lower Kitsumkalum brood were incubated in 10°C water from November 25 to the swim-up stage. When the fry were ponded on Jan. 10, they were reared in 8°C water for one month to initiate feeding, then transferred to unheated water for the rest of the rearing program.

The heated Cedar/Clear fry were fed at 100% of the recommended ration. The other groups were supposed to have been fed a 70% ration to retard their growth, such that they would reach a 2 g size at about the time the heated Cedar/Clear group would reach 5 g. During the actual rearing program, however, they were fed at 100% ration. The average monthly rearing temperatures for the heated and unheated groups are presented in Figure 15. Through February and March the heated water was maintained at 2.3-2.4°C above ambient. In April the heated water was maintained at an average of 0.8°C above ambient.

By the time the fry were released at the end of April, the heated Cedar/Clear fry had attained a weight of 4.4 g, or 0.6 g below the target of 5 g. The unheated lower Kitsumkalum and Cedar/Clear fry reached weights of 2.66 and 2.5 g respectively, 0.5-0.6 g over the target weight of 2 g. The unheated Kitsumkalum and Cedar/Clear groups grew at a similar rate to the 1981 and 1982 broods.

The heated group suffered much higher mortalities (19.5%) than the unheated groups (6.5%). This appears to have been due, in part, to poor water quality from the recirculation of heated water. The cold temperatures also could have helped to suppress mortalities. When the heated group was returned to ambient temperatures during April, mortalities dropped from 5% per week to 1.5-2.0% per week. There were many pinheads in all groups, but especially in the unheated group. Overall mortality from ponding to release was 12.9%. A summary of the survivals from planting to release is shown in Table 8.

TAGGING

Pilot I

A total of 44,580 chinook fry were tagged and released between May 25 and June 2, 1981 (Table 10). A further 18,842 were released unmarked due to their small

size. The marked fry were held for 1-3 days before being released 1.5 km below Treston Lake in the lower Kitsumkalum River. Pre-release mortality amounted to 277 fry, less than 1% of the total number tagged. An additional 30 fry were sacrificed during tagging to check tag placement.

Pilot II

A total of 88,367 chinook fry were tagged in 1982 (Table 10). Numbers of tags for each treatment group varied between 16,000 and 29,000. Delayed tag loss was 1% for all groups. A total of 68,729 fry were unmarked because of their small size (average weigh was 0.7 g). The Cedar/Clear brood reared in heated water was released at the Clear Creek bridge on April 20-22, 1982. The unheated Cedar/Clear brood was released at the Little Cedar River bridge on April 27-28. The heated and unheated lower Kitsumkalum broods were released 5 km below Treston Lake on May 5-6.

Pilot III

In 1983, a total of 57,160 fry Cedar/Clear fish were tagged (Table 10). No lower Kitsumkalum fry were tagged. Tag loss amounted to an average of 2.9% of the total number of Cedar/Clear fry released, although 18,402 were not tagged because of their small size.

TAG RECOVERY

The 1980 and 1981 brood year Kalum stock chinook were caught in both Canadian (60%) and Alaskan (40%) fisheries in the years 1984 to 1986 (Table 11). The major Canadian contributions were to the northern troll and northern net fisheries, with single catches in each of the central net, Johnstone Strait, freshwater sport and Georgia Strait sport fisheries. Most of the Alaskan catches were in the southeast Alaska central outside commercial troll fishery, with some from the southern and northern outside fishery and a groundfish observership in the Gulf of Alaska.

The total of 97,000 Kalum stock tagged releases have yielded an estimated 209 fishery recoveries to date, whereas the 94,000 Cedar stock releases have yielded an estimate of only 5 ocean recoveries. This reflects either a low survival or low interception rate for the 1981 brood Cedar stock, but the data set is

Table 11. Coded Tag Recoveries from the Kalum Pilot Hatchery Releases

Brood Year	Stock	Treatment	Recovery Year	Canadian Fisheries		Alaskan Fisheries		Escapement		Total Recoveries	
				Obs	Est	Obs	Est	Obs	Est	Obs	Est
1980	Kalum	Unheated	1984	7	30	5	22	-	-	12	52
Tag code: 021951			1985	7	32	5	23	9	39	21	94
Number Tagged: 44273			1986	5	17	2	2	11	64	18	83
Overall Survival: 0.52%			Total	19	79	12	45	20	103	51	227
1981	Cedar	Unheated	1984	-	-	-	-	-	-	-	-
Tag code: 022149			1985	1	1	-	-	1	4	2	5
Number Tagged: 16204			1986	-	-	-	-	-	1	-	-
Overall Survival: ?			Total	1	1	-	-	1	4	2	5
1981	Cedar	Unheated	1984	-	-	-	-	-	-	-	-
Tag code: 022311			1985	-	-	-	-	-	-	-	-
Number Tagged: 18937			1986	-	-	2	2	-	-	2	2
Overall Survival: ?			Total	-	-	2	2	-	-	2	2
1981	Kalum	Unheated	1984	-	-	-	-	-	-	-	-
Tag code: 022312			1985	1	4	2	7	-	-	3	11
Number Tagged: 23234			1986	5	16	1	11	11	64	17	91
Overall Survival: 0.44%			Total	6	20	3	18	11	64	20	102
1981	Kalum	Heated	1984	1	5	1	3	-	-	2	8
Tag code: 022313			1985	-	-	2	9	2	9	4	18
Number Tagged: 29459			1986	5	17	2	13	13	75	20	105
Overall Survival: 0.44%			Total	6	22	5	25	15	84	26	131
1982 Cedar Heated - only one recovery in Alaska in 1984 from 33872 tagged released											
1982 Cedar Unheated - no recoveries yet from 24987 tagged release											
Totals											
Kalum				31	121	20	88	46	252	97	461
Cedar				1	1	3	4	1	4	5	9

Obs = observed
Est = estimated

incomplete. The Kalum stock appears to return mainly as 4- and 5-year-olds, but the 6-year-old contribution by the 1981 brood will not be known until after the 1987 fishing season. The Cedar stock from the pilot has not contributed enough to any fishery to make an estimation of year-class strength. Results from the 1987 and 1988 fisheries (5-and 6-year olds for large releases in 1983) will hopefully improve this situation.

Escapement enumeration focussed on the Kalum stock in 1985 and 1986, with only one incidental catch of a Cedar stock tagged fish. Again, the data set is incomplete until the 6-year old returns of the 1981 brood are counted in 1987.

It should be noted that the returns noted in Table 11 do not include counts of adults in:

1. the high seas fishery
2. the native food fishery
3. pre-1984 or post 1986 fisheries
4. escapements before or after the study periods
5. escapements to the Cedar River, Clear or Dry Creeks.

Even so, the survival rates accumulated to date (0.52% for 1980 brood and 0.44% for 1981 brood Kalum stock) are extremely low, less than half the survivals expected from coastal streams but in the same range as releases from recent Interior hatcheries (C. Cross, pers. comm.).

DISCUSSION

PILOT I

The main problem resulting from the 1980/81 pilot was that the fry only attained an average size of 1.3 g by the time of wild stock emigration. The small size was attributed to two problems:

(i) The growth rate was depressed due to health problems. Some coagulated yolk was noticed during incubation and emergent fry had symptoms resembling furunculosis.

(ii) The fry were cultured in temperatures below 6°C. The cold temperature may have reduced mortality but it also slowed the egg and alevin development rate and fry growth rate.

During rearing, health problems were first attributed to furunculosis, then to overcrowding and "Yolk sac" disease. Excessive gas pressures may have caused these problems. Gas saturation measurements before and after the Pilot operation showed readings in excess of 110% nitrogen saturation and 105% total gas pressure, above the recommended maxima of 102% and 103% respectively. Symptoms of gas bubble disease, caused by the formation of bubbles within the body of the fish from excessive dissolved gas pressures, include large bubbles in the abdomen posterior to the yolk sac, coagulated yolk, secondary bacterial infections and frayed fins (Sigma, 1983). Some of these symptoms were similar to those seen in fish at the Kalum Pilot hatchery.

A further problem encountered by the first pilot was a high egg mortality between fertilization and the eyed stage. In 1980, the high incubation mortalities may have been due to the disturbance of incubating eggs caused by successive plantings of eggs from the small egg takes. It was felt that the installation of tray incubators would allow eggs to be planted without disturbing the eggs from previous egg takes.

The low survival rate shown in tag returns from the 1980 brood were not surprising considering the poor condition of the fish, the small release size and the inland location of the facility.

PILOT II

Since the Dry Creek water temperatures were confirmed to be too cool for rearing by the results of Pilot I, sources of warm water were investigated. Surface water from Clear Creek could not be used because temperatures did not increase above those of Dry Creek until April. Surface temperatures in a beaver pond 1.0 km from the hatchery site were significantly warmer than the hatchery supply when measured in May of 1981. It was therefore thought that the water temperatures in the beaver pond just downstream of the hatchery might show a similar increase. This, however, was an unproven assumption that needed further investigation in Pilot II. To ensure a warmer supply of water, it was decided to heat the Dry Creek water with industrial electric water heaters, despite the high expense.

To increase the success of the hatchery, the following changes were made for the 1981/82 pilot:

(i) Four more Capilano rearing troughs were installed to increase rearing capacity.

(ii) To improve the supersaturated gas situation, a cascade aerator was placed just below the upper spring and packed column aerators were placed at the head end of the new trough lines.

(iii) Electric heaters were installed to increase water temperatures for rearing.

(iv) Two rearing troughs were placed just below the beaver pond to test the use of solar heated pond water to increase fry growth.

(v) One eight-tray incubator stack was installed to help alleviate problems associated with successive small egg takes.

Although the hatchery had experienced some problems in its first year, it was thought to be moderately successful, so the egg-take targets were increased for the 1981/82 Pilot to 100,000 eggs for each of the lower Kitsumkalum and Cedar/Clear stocks. This was also expected to provide enough released fish to provide statistically significant returns of adults for survival calculations.

Incubation in tray stacks was found to be an improvement over the gravel boxes in terms of both survival and control of ponding time. There was a higher survival to the eyed stage in 1982, possibly because successive plantings of eggs in the gravel boxes were avoided. After the eyed stage, there was 22.5% survival from egg pick to emergence from the gravel boxes compared to insignificant mortality from the trays. The trays also allowed all the fry to be ponded on one day whereas the lower Kitsumkalum fry emerged from the gravel boxes over a period of 87 days. The long period of emergence decreased rearing time and hampered comparisons of growth rates between groups of fry.

The heaters initially provided an average increase in water temperatures of 1°C, but as time passed their performance decreased. By the end of April, the water temperatures were only increased 0.2-0.3°C. When the Cedar/Clear fry were transferred to unheated water after being in heated water, the growth rates of the heated and unheated groups remained fairly similar because of the small difference in water temperature. Due to the decline in the heated water temperatures, the fry reared in heated water did not attain the size that was expected. It appears that decreases in heater performance occurred because the heating elements became fouled with fish food and feces.

The lower Kitsumkalum fry maintained higher growth rates in 1982 than in 1981 even after being transferred to unheated water. The main reason for the higher growth rates was that Dry Creek temperatures were 0.7-1.0°C higher in April and May of 1982 than in 1981.

Despite the addition of aeration devices, fish health continued to be a problem in 1982. The pinheading and poor condition of the fry was probably caused by the poor quality of the recirculated water, which was inadequately treated. No specific pathogens were identified.

The fry released by the 1981/82 pilot were larger than those released from the 1980/81 pilot because of the warmer rearing temperatures. The Cedar/Clear fry were released at an average of 3.2 g, compared to the 1.4 g size that the 1980 lower Kitsumkalum fry attained after a comparable rearing time. This differential was mainly due to the earlier spawning timing of the Cedar stock, allowing for a longer rearing time.

The smolt-to-adult survival data to date indicates no difference between the heated and unheated Kalum groups, which is reasonable considering their release sizes were not very different. Lack of return data for Cedar fish may be due to low survivals or to a greater age at maturity. Return data for 1987 and 1988 should improve this data set.

Temperatures monitored in the beaver pond showed that the pond was not warmed sufficiently during the spring to allow it to provide much higher temperatures for rearing because the flushing rate of the pond was too great.

In summary, Pilot II produced fry of larger size than Pilot I, but failed to meet the target of 5 g fish because the heaters became fouled. The natural water sources at the Dry Creek site were confirmed to be too cool to rear fry to a suitable size. The cost of rearing fry on artificially heated water proved to be prohibitive for a production facility, even with partial recirculation. Incubator trays, however, provided for lower mortalities during incubation and allowed better control of ponding than gravel incubation boxes.

PILOT III

It was recognized that the Dry Creek site was not suitable for a production facility because it would not be economical to provide warmer water for incubation and rearing. The emphasis for the pilot was changed from site testing to production of fry of different sizes for the 1982/83 operation. It was decided to attempt to release 2 g versus 5 g fry on the same date for comparison of their survivals to adult. The Cedar/Clear stock as selected for this study, rather than the lower Kitsumkalum stock, because the Cedar/Clear spawners were thought to be easier to enumerate and their earlier spawning would allow production of large, as well as small, fry for release.

The following changes were made to the facility for Pilot III in 1982/83:

(i) The gravel boxes were replaced by more vertical incubator tray stacks to allow better control over ponding times.

(ii) Some of the tray stacks were connected to the heated water line, so that incubation time could be decreased.

(iii) The heaters were to be cleaned weekly during operation.

The operational plan called for the Cedar/Clear brood to be reared in heated water until the end of April. However, problems with the generator prevented heated water from being used through most of April, subsequently causing a decline in the growth rate of the fry. The operational plan also called for the unheated groups to be fed at 0.7 of maximum ration, to slow their growth so they attained a weight of 2 g by the last half of April. In practise, the fry were fed to 100% of maximum ration which caused their growth to exceed the projected rate. The result was that instead of a 3 g difference in the size of the two groups of fry, there was approximately a 2 g difference.

Pilot III was moderately successful in producing two groups of fry of different sizes on the same release date. The heated Cedar/Clear brood attained an average weight of 4.4 g compared to the target of 5 g. The unheated Cedar/Clear and lower Kitsumkalum broods were raised to approximately 2.5 g, or 0.5 g over the target.

Again, health continued to be a problem. Despite all the eggs being incubated in tray stacks, there were high mortalities from the time of planting to the eyed stage. This was particularly true of the Cedar/Clear stock. It is possible that the mortalities of the Cedar/Clear group were high due to stressful handling of the adults prior to the egg take, when 50% of the females being held died.

It is too early to assess whether the lack of observed adults in the fishery to date is of consequence. It is strongly recommended that programs to recover tags from spawners in the Cedar River area be conducted in 1987 and 1988, to complete the time-and-size release assessment.

CONCLUSIONS

The Dry Creek spring water used at the Kalum Pilot facility would require two types of treatment before it would be suitable to supply a full scale facility:

1. Heating. The water is not warm enough in the fall and spring to provide swim-up fry early enough for ponding before the temperature decreases sufficiently to make initiation of feeding difficult, especially for the later spawning lower Kitsumkalum stock. The least expensive solution is to provide heated incubation water several degrees above ambient even during Dry Creek's warmest period, so that the fry can be ponded into water warm enough to initiate feeding. Alternately or additionally, heating of water at ponding would help to initiate feeding. Once feeding was well established, the fish seemed to grow well even in cold water in a decreasing temperature regime.

2. Aeration/stripping. Although the aeration structures were upgraded after health problems were encountered, they were never sufficient to reduce nitrogen supersaturation to a level low enough to be harmless. Since this problem was not adequately attended to during the pilot operation, it is still uncertain whether it merely contributed to or was the only cause of health problems.

In conclusion, the Kalum Pilot facility results indicate that the main attractions of Dry Creek as a potential water supply -- gravity feed and warm winter temperatures -- are not sufficient to outweigh the cold fall and spring temperatures and the large aeration requirement. If a hatchery in the Skeena River system requires heated and pumped water, it would be better placed in a less remote location.

For cold water rearing, it is concluded that even short term heating of water provides a better initiation of feeding, leading to better growth, survival and health of the fish for the subsequent cold water rearing program.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of the following people on the Kalum Pilot Project:

For construction of the facility, SEP Engineering staff, especially A. Rowland and the late S. Watanabe.

For operation of the pilot, R. Hilland, S. Barnetson, D. McNeil, D. Parmenter and M. Drewes.

For review of the manuscript, D. McNeil, R. Hilland, F.K. Sandercock, A. Rowland and especially B.G. Shepherd.

Special thanks to D. Parmenter for allowing SEP to set up the Pilot on his land and for his cooperation and assistance throughout the study.

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